Multi-scale finite element modeling of structural materials

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Two-scale finite element analysis based on mathematical homogenization method is one of coupling approaches between macro-scale and micro-scale. In this approach, the micro-scale finite element analyses behave as the macroscopic constitutive model at macro-scale. This methodology is sophisticated, however its application to practical nonlinear problem is difficult due to the high computational efforts. Therefore we proposed the micro-macro decoupled scheme to overcome this practical obstacle[1]. Here a computational evaluation framework, where the macro-scale boundary value problem is reduced to macroscopic stress-strain relationship in two-scale boundary value problem, was called as Numerical Material Testing.

Namely modeling of microstructure is the key element in this framework, but this subject is challenging for structural metallic materials. For example, there is no design layout for microstructure, then we often employ microstructure with idealized geometry. Another way is image-based modeling. Recently advancing observation techniques provide 3D morphology data of microstructure. Based on such observation data, a finite element model of microstructure is made with a geometry extraction method.

Constitutive modeling is an important topic in finite element modeling. Some constitutive models have been developed to characterize material behaviors from a microscopic view point; e.g. single crystal plasticity coupling with continuum damage theory[2], anisotropic plasticity for lamellar microstructure[3] etc. A major difficulty is the determination of material constants of nonlinear constitutive models. For this subject, some attempts has been conducted to create a framework to characterize the material behavior by coupling with microscopic material testing and physical computations.

References:

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